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(54) PHOTOMETRIC MONITORING APPARATUS

(71) We, COMMISSARIAT A L'ENERGIE ATOMIQUE, an organisation created in France by ordinance No. 45-2563 of 18th October 1945, of 29 Rue de la Federation, Paris 15e, France, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement: —

The invention relates to a method of photometrically monitoring an optical characteristic of an article and also to apparatus for carrying out this method.

It applies more particularly, but not exclusively, to the photometric monitoring of a radiographic record, and more particularly still to the examination of radiographs of clad plates of fuel material, used in certain types of nuclear reactor in which the core is cooled by water which also acts as the netron moderator. The fuel plates are generally in the form of a relatively thin strip of fuel material, usually aluminium- and uranium-based and possibly enriched, surrounded on each face by a layer of protective and cladding material, more particularly aluminium, of constant thickness. It is, of course, highly desirable to known the homogeneity of the fuel alloy within each of the fuel plates so formed, so that the uranium charge per unit area can be monitored. This charge must lie between an upper limit and a lower limit which define the tolerances permitted relative to the nominal charge.

The invention provides a method of photometrically monitoring an optical characteristic of an article comprising the steps of photometrically scanning in a series of passes a plurality of portions of the article, one pass for each portion, and for each said portion of the article detecting from the scan, and storing a first and second reference value of the characteristic, and comparing the values of the characteristic of the article obtained during scanning with the stored first and second reference values.

The invention also provides apparatus for carrying out the method according to any preceding claim including a reading head, an article support table, means for causing relative movement between the reading head and support table for scanning the article, means for detecting the first and second reference values by the reading head, means for storing the first and second reference values, and means for comparing the values of the characteristic of the article with the stored first and second reference values.

Features and advantages of the invention will be apparent from the following description of embodiments thereof, given by way of example only, in conjunction with the accompanying drawings, in which: —

Figure 1 is a plan view of monitoring apparatus for carrying out the method according to the invention;

Figure 2 illustrates diagrammatically the optical device provided on the carriage of the apparatus of Figure 1 and forming the reading head;

Figure 3 is a diagram of the electronic control circuit of the apparatus of Figure 1; and

Figure 4 illustrates the preparation of, and the manner in which the photometric scanning of, a photographic record by the reading head takes place.

Referring to Figure 1, the monitoring apparatus includes a base 1 for a framework 2. A plate 3, applied to this framework and locked in position, supports a driving and reducing unit 4 by means of which the various components of the apparatus can be operated. This driving and reducing unit con-

tains an electric motor 5 whose output shaft is directly associated with a speed reducer 6. The latter, by way of a flexible coupling 7, drives an electromagnetic coupling 8, by means of which, in particular, all the components operated by the unit can be immediately stopped. The coupling 8 drives a bevel gear 9 meshing with a second gear 10, mounted in turn on the end of a rod 11 which extends through the framework 2 to a handle 12. If the driving and reducing unit is disconnected, the handle can be used as a manual substitute for it. A wheel 13, mounted on the same shaft as the gear 9, can entrain with its rotary movement a chain 14 whose role will be explained below. The same shaft also carries a straight gear 15 meshing with a second gear 16. The axle of the second gear 16, after passing through a speed reducer 17, rotates a transmission shaft 18 whose end, mounted in a bearing 19, is attached to a wheel 20 for driving a second chain 21. The latter is mounted in turn on a second wheel 22, attached to a shaft 23 which is supported in bearings 24, 25 attached to the framework 2. The shaft 23 has a helical thread 26 extending over most of its length and forms a lead screw for controlling displacement of a carriage 27 parallel to the direction of the shaft 23. The carriage is mounted in a slideway 28 parallel to the shaft 23 and has a nut 29 co-operating with the screw in such a way that rotation of the screw produces longitudinal translatory displacement of the carriage 27 along its slideway 28. Advantageously, the nut 29 is in two separable portions, so that it can be disconnected from the control screw, by means of a cam device 30 operated by a control lever 31. If the driving motor 5 fails, the carriage 27 can be displaced by means of a manual control: to this end, the speed reducer 6 is directly connected to a handle 33 by means of a mechanical connection 32. Also, the speed of movement of the carriage may be increased or reduced as desired by means of a second connection 34, co-operating with a handle 35 and acting on the speed reducer 17 which, by way of the shaft 18, controls rotation of the chain wheels 20, 22.

On the framework 2 there are two mutually parallel guides 36, 37 orientated at right-angles to the slideway 28 for the carriage 27. These guides carry a support table 38 for a radiographic record plate 39, which is to be monitored by a reading head (described in detail below) mounted on the carriage 27. This table 38 is reciprocated on its guides 36, 37 by means of two studs 40, 41, which are mounted on the lateral surface of the table and co-operate respectively with two connecting rods 42, 43 engaged in two crank pins 44, 45 belonging to two parallel disc cranks 46, 47. The two disc cranks are connected by a transverse shaft 48 supported by the framework 2, parallel to the common direction of the shaft 23 and slideway 28. The shaft 48 carries a wheel 49 which is situated opposite the wheel 13 and co-operates with the chain 14 of the latter.

The monitoring apparatus also includes a visual indicating means permitting graphic representation of the movement of the reading head on the carriage 27 relative to the radiographic plate 39 during the longitudinal displacement of the carriage and the transverse reciprocation of the table 38. To this end, the shaft 23 is associated, beyond the chain wheel 22, with a second wheel 50 which, by way of a chain 51, drives another wheel 52 mounted at the end of the shaft 53 of a multi-ratio gear box 54. The output shaft 55 of the box carries a bevel gear 56, meshing with a second gear 57 whose axle has a straight gear 59 at its other end. This gear 59, by way of another straight gear 60, drives a roll 61 mounted on a support 62 fixed to the apparatus base 1. The roll 61 forms a continuous drive for a paper strip 63, which may be a strip of electrolytic paper, co-operating with the end 64 of a pen 65. The pen is pivotally mounted at two places: at a pivot 66 mounted on a shoulder 67 of the box 54, and, at its end, on a pivot 68 mounted on a shoulder 69 projecting from the table 38. As a result, the pen 65 is caused to carry out a reciprocating movement transmitted by the table 38, the amplitude of this movement being in a given ratio to that of the displacement of this table in its guides 36, 37 according to the position of the pivot 66. Advantageously, the latter can occupy three different positions, so that the end 64 of the pen 65 can move on the paper strip 63 in the ratio of 1/1, 1/2 or 1/4 to the movement of the table bearing the radiographic plate 39. Similarly, the box 54 is such that the speed of movement of the paper strip 63 can be brought as desired into a ratio of 1/1, 1/2 or 1/4 to that of the movement of the reading head on the carriage 27.

Figure 2 is a detailed general diagram of the reading head. The head has a highly stable light source 70, the light from which is focused by a prism 71 and condenser 72 on a diaphragm 73 in order to give a point image of the source 70. This point source illuminates the radiographic record 39 mounted on the table 38 through a lens 74. The portion of the record so illuminated acts as an object, the image of which, retransmitted through a second prism 75 and a lens assembly 76, is formed in the plane of a rectangular diaphragm 77 having an adjustable aperture. The quantity of light traversing the aperture then illuminates the window of a photomultiplier 78, whose output current represents this quantity of light and, correlatively, the opacity of the record 39. A safety device for the photomultiplier is mounted in

the reading head, and has a shutter 79 controlled by a rotary electromagnet 80. The shutter obscures the photomultiplier window when the incident light exceeds a given intensity. Lastly, two photoelectric reference cells 81, 82, mounted on the diaphragm 77, are adapted to detect, as will be described later, in the image of the photographic record 39 transmitted by the optical system, the references intended to serve as standards for measuring.

Figure 3 illustrates diagrammatically the electronic apparatus associated with the reading head. The photomultiplier 78 has a very high-tension electricity supply 83, and is connected at its output to two storage devices 84, 85. The two reference cells 81, 82 trigger the storage devices 84, 85 to accept and store the reference datum values produced when the photometric head passes over the reference strips. These reference values correspond respectively to a "maximum" and a "minimum" threshold for the optical characteristic measured. A given coefficient may or may not be allotted to the stored values in two corrector circuits 86, 87. The photomultiplier 78 is also connected to two comparators 88, 89 which receive the values of the characteristic of the article produced by a pass of the photomultiplier 78 across the article. The reference signals from circuits 86, 87 are then each compared at each instant with the photomultiplier signal in comparators 88, 89 each of which produces a signal which is converted into logical form in circuits 90, 91, respectively associated with the two comparators, so that a final output signal, formed in circuit 92, is sent to a recorder to provide the following levels:

level 0 for opacity between the reference values;

level 1 for opacity greater than the maximum opacity;

and

level 2 for opacity less than the minimum opacity.

Operation of the above described monitoring apparatus consists essentially in scanning in a series of passes a plurality of different areas on the surface of the record plate 39 (after this plate has been positioned on the table 38) by the simultaneous combination of the reciprocating displacement of the table and the longitudinal displacement of the carriage carrying the reading head. As already described, the radiographic record 39 to be examined is, by way of example but not by way of limitation, a record of a fuel plate 101, having cladding 102, more particularly of aluminium, surrounding a thin strip of uranium-aluminium alloy 103, the homogeneity and the distribution of the uranium charge of which is to be monitored. In this example, the plate 101 (see Figure 4) is mounted between two aluminium reference strips 104, 105, whose thickness is such that their X-ray absorption is exactly representative of the minimum and maximum uranium contents tolerated.

The photometric measuring operation consists in measuring, during movement of the reading head across the radiographic record 39, the relative opacity of each point illuminated by the reading head of Figure 2, then comparing the value measured at each instant with the reference values produced by the radiographic image of the reference strips 104, 105, and placed into the storage devices 84, 85. For each pass of the reading head over the table supporting the record, these reference values are stored, and compared in comparators 88, 89 with the values of the characteristic supplied by the reading head. The apparatus can therefore record, within a very short time, signals corresponding to the tolerance limits accepted and to the zero value for the uranium charge in the fuel plate and can simultaneously interpret these signals, comparing them with the reference values, new values which are obtained for each pass during the whole of the examination.

It is therefore possible to eliminate the causes of errors due, especially, to variations in opacity resulting from processing of the radiographic record while it is developed, particularly when the length of the fuel plate examined is considerable, of the order of a metre. Also eliminated are errors due to the fact that the X-ray field by which the radiograph is made, is not constant from one point to another since it depends on the position relative to the source. Moreover, the reader head can give immediate reproduction of the measurements thus obtained, for example making black regions correspond to those having a content greater than the maximum tolerance, grey regions correspond to a content less than the minimum tolerance, and white regions correspond to a content of uranium in the plate which is within the range between these tolerances, these regions being characterised by logical levels previously defined.

Obviously, when the apparatus is used, numerous operating parameters may be varied, for example the divergence or length of the photomultiplier window of the measuring head, the degree of longitudinal displacement of the carriage, the transverse course of the table carrying the record, or the speed of scanning. Also, it should be understood that the method according to the invention is not applicable solely to the measurement of relative opacity of a radioactive record, but can be used to monitor any given optical characteristic of an article such as its reflectivity or its coefficient of refraction. In particular, by means of the method and setting the two reference values sufficiently close

to one another, a line can be readily determined on such an article where such a characteristic is constant, for example an isodensity line can be determined if the characteristic is the opacity of the article examined. According to another variant, the method concerned may permit recording of the average values along an axis of a certain zone, in which case, every time the reading head passes a given place, the measurement obtained is converted into discrete levels and sent to an integrating counter. The average value in the zone can then be obtained directly by reading the counter. Lastly, the recording system may be in the form of a table carrying out two perpendicular movements, the reading head being fixed. This table would be associated with a particular marking device permitting immediate presentation of the results. In another arrangement the results of the comparison of the signals from the reading head with the reference values may be recorded on magnetic tapes, and analysed with a computer.

WHAT WE CLAIM IS:—

1. A method of photometrically monitoring an optical characteristic of an article comprising the steps of photometrically scanning in a series of passes a plurality of portions of the article, one pass for each portion, and for each said portion of the article detecting from the scan, and storing a first and second reference value of the characteristic, and comparing the values of the characteristic of the article obtained during scanning with the stored first and second reference values.

2. A method according to claim 1 wherein the first and second reference values are detected in positions situated at opposite ends of each pass.

3. A method as claimed in claim 1 or 2 wherein one of the reference values is detected after each pass across the article.

4. A method as claimed in claim 3 wherein the reference values detected after a pass across the article is placed into store as a reference value for the following pass across the article.

5. A method as claimed in any one of the preceding claims wherein the optical characteristic is the opacity of the article or its reflectivity or its coefficient of refraction.

6. A method as claimed in any one of the preceding claims wherein the reference values stores are the maximum and minimum tolerances permitted for the characteristic.

7. A method as claimed in any one of the preceding claims wherein the article is a radiographic or like record including portions thereof from which the reference values for each respective portion of the article are detected.

8. A method of photometrically monitoring an optical characteristic of an article substantially as herein described with reference to, and as illustrated in, the accompanying drawings.

9. Apparatus for carrying out the method according to any preceding claim including a reading head, an article support table, means for causing relative movement between the reading head and support table for scanning the article, means for detecting the first and second reference values by the reading head, means for storing the first and second reference values, and means for comparing the values of the characteristic of the article with the stored first and second reference values.

10. Apparatus according to claim 9 wherein the means for causing relative movement between the reading head and the support table comprises means for reciprocating the support table in a plane and drive means for translating the reading head in a direction perpendicular to the direction of reciprocation of the table so that the reading head scans an article supported on the support table in a series of reciprocations.

11. Apparatus according to claim 10 including means for visually indicating the relative positions of the reading head and support table.

12. Apparatus as claimed in claim 11 wherein the indicating means includes a gearbox for transmitting the rotary movement of the lead screw to a drum for driving the paper strip.

13. Apparatus as claimed in claim 11 or 12 wherein a recording pen is mounted for oscillation about an axis whose position is adjustable, and the pen is attached to a shoulder on the support table.

14. Apparatus as claimed in any one of claims 10 to 13 wherein the reading head is mounted in a slideway and co-operates by means of a nut with a lead screw for translating the reading head.

15. Apparatus as claimed in claim 14 wherein the nut is in two portions movable away from each other to disconnect the carriage from the lead screw.

16. Apparatus as claimed in any one of claims 10 to 15 wherein the reciprocating means includes at least one connecting-rod/disc-crank assembly and the support table co-operates with two guides parallel to the reciprocation direction.

17. Apparatus as claimed in any one of claims 10 to 16, and including a driving and reducing mechanism with a torque-limiting device and for driving by way of an electromagnetic coupling the reading head and support table.

18. Apparatus as claimed in claim 17, wherein the said mechanism includes a motor, and also a handle for manually driving the mechanism when the motor is inoperative.

19. Apparatus as claimed in any one of claims 9 to 19, wherein the reading head in-

cludes a light source for illuminating the article to produce an image of the article in the plane of a diaphragm whose aperture is adjustable and which is situated in front of the window of a measuring photomultiplier.

20. Apparatus as claimed in claim 19, wherein the diaphragm incorporates at least one photoelectric cell for detecting the reference value in the image of a reference article.

21. Apparatus for carrying out the method of claim 1, substantially as herein described with reference to, and as illustrated in, the accompanying drawings.

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1279019 COMPLETE SPECIFICATION
3 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 1

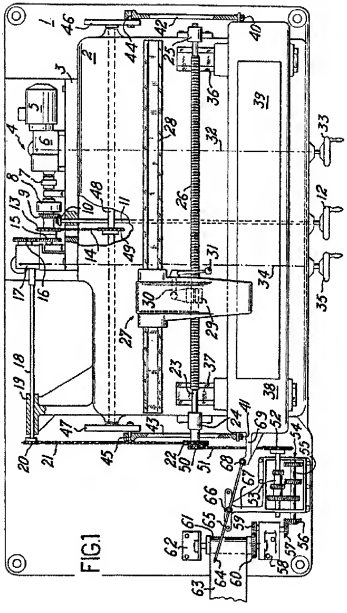

FIG.1

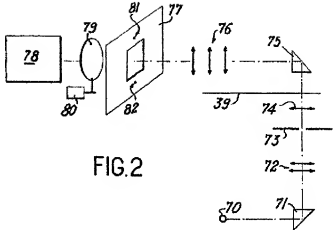
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FIG.2

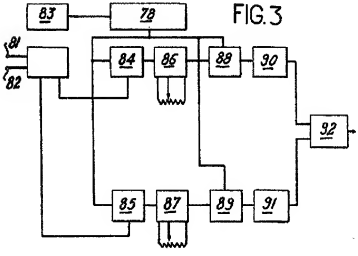
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FIG.3

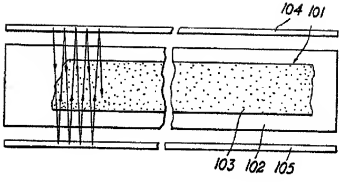

FIG.4